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AMERICAN METEOROLOGICAL JOURNAL.

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THE AMERICAN

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VOL. III. ANN ARBOR, NOVEMBER, 1886. No. 7.

CURRENT NOTES.

LAKE GLAZIER.—In the first volume of this JOURNAL was published Capt. Glazier's account of his professed journey to the headwaters of the Mississippi river. I took the trouble to inquire, before publishing, from private sources, as to Capt. Glazier's responsibility and received entirely satisfactory assurances on that head. I did not, however, take the pains to compare his articles with Schoolcraft's "Narrative" and it has remained for Mr. Henry D. Harrower to point out very remarkable correspondences between Glazier's account and Schoolcraft's, written fifty years before. It has always been stated explicitly that the editors of this JOURNAL do not hold themselves responsible for the correctness of matter signed by others, though they endeavor to take reasonable precaution against being led into error. Mr. Harrower's publication is made by the eminent firm of publishers, Ivison, Blakeman, Taylor & Co., and it is a part of their study of the correctness of Glazier's announcement. They have also sent a surveying party to Lake Itasca to settle the matter still more definitely. The report of this party is not yet published, but I judge from their announcement that it can be expected soon. The enterprise is a notable one and very creditable to the firm. M. W. H.

PRAIRIE FIRES IN INDIAN TERRITORY.—In the early autumn the most extensive and destructive fires ever known in that region prevailed in the Indian Territory. Millions of acres of

rich grazing lands, which a few days before were covered with a luxurious growth of grass, became barren, charred wastes. The area burned over extends from Vinita on the north to Muskogee on the south, and on either side of the Missouri, Kansas and Texas railroad as far as the eye can see. Large numbers of cattle were burned to death, and immense quantities of hay, baled and loose, which was to have been used for fodder during the winter, were destroyed, and cattle men were obliged to drive their herds elsewhere to save them from starvation. An investigation into the origin of the fire is to be made by the Vinita Indian agent.

PERIODICITY IN DROUTHS.—"There is a curious periodicity," says the *Coast Review*, "in the drouths in the western states, and as there is usually some relation between fires and drouths, underwriters are interested in the matter. We have observed that a more or less severe drouth occurs every seven years in the Missouri Valley states, and this periodicity is particularly notable in Kansas. In 1860 there was a very severe drouth lasting eighteen months. The inhabitants were saved from starvation by the contributions of the charitable. Boston shelled out its beans, and Senator Pomeroy secured fame and a name—Old Beans—through the judicious distribution of that leguminous vegetable to his starving constituency. In 1867 there was another drouth, but it was comparatively mild. In 1874 there was a severe drouth, extending throughout all the states west of the Mississippi river. The year 1881 was a drouthy year, also, west of the Missouri. If the seven-year period continues to 'hold good,' 1888 will be a very dry year throughout the territory referred to. The drouthy year has always been preceded by a dry year or two, and is usually succeeded by a year of copious rains, including a reign of prosperity. But in the dry and unprosperous years more than ordinary care in the acceptance of risks might be profitably used."

FORESTS CONSUMED FOR RAILROAD TIES.—A government report has been made in regard to the consumption of forests for

the purpose of furnishing ties for our 150,000 miles of railroad. The report shows the amount and kind of wood employed by about 63 per cent. of the roads,—all who would report. From this report it appears that to furnish ties for our present mileage of roads has taken the available timber from an area of land equal to that of the states of Rhode Island and Connecticut, and, estimating that the ties will be renewed once in seven years, there will be required for this purpose, and to equip the new roads built from year to year, the timber growing on 565,714 acres. Allowing again, that a growth of thirty years is necessary to produce trees of proper dimensions for ties, it will require 16,971,420 acres of woodland to be held as a kind of railroad reserve in order to supply the annual needs of the roads, not to speak of greater expansion of the railroad system. This makes an area larger than New Hampshire, Vermont, and Massachusetts combined. It is more than four per cent. of the woodland of the United States, exclusive of Alaska.

Losses on the Great Lakes.—The Detroit *Free Press* is our authority for the statement that the losses on the Great Lakes have, to November 11th of this year, amounted to about $800,000. An unusual feature in the losses is that, of twenty-six vessels lost, fifteen went down in deep water. This is more than half and is an unusually large proportion. Of the vessels lost this year, three ran on rocks, four were run down, three sprung a leak, one broke from her moorings and went on a reef, and four foundered, three because of overloading. Some of the losses were due to the elements and were unavoidable, but perhaps more were due to moral causes, such as overloading or carelessness. The *Free Press* quotes an old lake skipper as saying that when freights were high losses were also always high. With a high price for freights the average owner can not resist the temptation to overload and take all risks. During the season of 1885, sixty vessels, of which twenty-two were steam and thirty-eight sail craft, passed out of existence, involving a loss of $1,016,200. Fourteen of these sunk, twenty-two went ashore, nineteen were burned, four capsized and were broken up by the seas,

and one, the tug Frank Moffat, was blown to pieces at Sombra by the explosion of her boilers. The wreck of the steamer Algoma at Isle Royale, L. S., on November 7, involving a loss of $300,000, was the chief disaster on the lakes in 1885, and this year, the sinking of the steamer Oconto in the St. Lawrence river, by which $100,000 worth of property was lost.

STATE BOARDS OF HEALTH.—Four more State Boards of Health says Dr. Rausch, as quoted by the *Sanitarian*, were established in 1885–86, the list now comprising the following thirty-one organizations, the dates of the establishment of which are prefixed: In 1869, Massachusetts; in 1870, California; in 1872, Minnesota; in 1873, Alabama, Michigan, Wisconsin; in 1874, Maryland; in 1876, Colorado, Louisiana, New Jersey; in 1877, Illinois, Mississippi, Rhode Island, Tennessee; in 1878, Connecticut, Kentucky, North Carolina; in 1879, Delaware, Iowa, South Carolina; in 1880, New York, West Virginia; in 1881, Arkansas, Indiana, New Hampshire; in 1883, Missouri; in 1885, Dakota, Kansas, Maine, Pennsylvania; and in 1886, Ohio.

THE CURVATURE IN RISING AND FALLING BAROGRAMS.—In a recent paper Mr. Abercromby points out that this is only a question of the rate of change. A falling barogram is convex when the rate of fall is increasing and concave when it is decreasing; and, conversely, a rising barogram is convex when the rate is decreasing, and concave when it is increasing.

As the rate of barometric change is proportional to the steepness of the gradients which are passing, and the wind also depends on the gradients, he is able to lay down the following rules for estimating the coming force of a gale from the inspection of a barogram. A convex barogram is always a bad sign with a falling barometer, and a good sign with a rising one. A concave trace is sometimes a good sign with a falling barometer, but not always a bad indication with a rising barometer. The convexity or concavity of a thermogram is in the same way shown to depend on the rate of thermal change. In the same article the author gives a method by which the distribution of diurnal

isothermals over the globe can be deduced from the diurnal thermograms in different latitudes; and shows that the shape of diurnal isotherms on a Mercator chart, for a limited number of degrees of latitude, is similar to the shape of the curve of diurnal temperature range, if time be turned into longitude, and temperature into latitude, on a suitable scale.

ARTESIAN WELLS WANTED.—In a recent number of the *Consular Reports* note is made of artesian wells wanted in various parts of Mexico. Public attention seems to be directed to the subject there and any one who could put the wells down would receive a warm welcome. In Tamaulipas wells are very generally needed and the prospects for them are unusually good. It is an excellent grazing state,—one of the best,—and successful wells would much emhance the value of property. In Coahuila the prospects of successful wells is not so good but the profits would be larger. Nuevo Leon also needs the wells very much. In fact they would be welcome on any of the border Mexican states. In other states they are needed in certain localities. In Oaxaca the district of Juchitan forms a very promising field for the undertaking. Villa Nueva in Zacatecas considers the opening of an artesian well near the city a necessity. In many places the construction of dams or construction or improvements of tanks would be profitable enterprises. The great tanks already erected in many places could be improved on and others are needed. Here is an excellent opening for hydraulic engineers. Among the needs especially noted, we may mention tanks in the canton of Lagos in Jalisco and a large dam on the Medina river at a suitable place where a large amount of land might be irrigated.

PEAT SLIDE IN THE FALKLAND ISLANDS.—Later advices concerning the peat slide at Stanley, on June 2nd last, show that it was a remarkable one of its kind. The town lies on the shore and above it stretches an immense plain of peat. This has no direct outlet and after heavy rains it becomes full of water, and tends to swell. A rain of three days increased its volume so much that

it finally welled over with a loud sound, and thousands of tons flowed down upon the town. The force of the slide was great enough to carry away lamp-posts and porches and to overthrow even stone walls. The phenomenon happened at night and lasted an hour.

This is, by no means, an unique phenomenon. Peat bogs occasionally well over in other parts of the world. One of the most notable was that of Solway Moss in December, 1771. After heavy rains, upwards of four acres of it rose to such a height that at last it rolled onward like a torrent. It continued its course above a mile and swept along trees, houses, and everything in its way. It finally divided up into islands of varied extent and from one to ten feet deep. It covered nearly 600 acres at Netherby, and is said to have destroyed not less than thirty small villages. Its motion continued from Saturday until Wednesday, the last day of the month.

A remarkable feature of the Falkland peat is that it is made, not of moss, but mostly of shrubby plants, the commonest being the crowberry (*Empetrum rubrum*) a near relation of a small shrub common in our northern bogs. With this is commonly found a little creeping myrtle and a dwarf marsh-marigold, as well as some sedge-like plants. Doubtless the resistance of these plants to the strain made the avalanche all the worse when they did give way. The Falklands lie in latitude 52° S. They are treeless and their climate is mild but wet and cloudy. They are devoted to cattle-raising.

TILLAGE AS A REMEDY FOR DROUTHS.—Undoubtedly much of the damage done farmers by dry seasons could be prevented if evaporation from the soil could be checked. While dryness of the air is injurious that of the soil is much more so, and, whether the soil becomes so dry that the plants can not draw from it their supply of water or so baked that they can not extend their roots in it, the results are always damaging and may prove fatal.

The surface evaporation can be largely prevented by proper tillage. If a thin layer of soil is frequently turned and properly pulverized not only is baking and cracking prevented, but the

loosened layer, by becoming dry throughout, serves to check evaporation from below. The moisture is thus kept for the roots of vegetation and they are able to sustain a much severer drouth than if it was allowed to escape freely in the air. Capillary rising of the moisture brings up that from the deeper layers but acts so feebly through the pulverized, tilled surface that it is retained just below the surface until utilized by vegetation.

These facts are well understood by the irrigating farmers of the extreme west. Great economy of water can be practiced without injury if the surface is constantly tilled, and in some places, when eastern farmers would consider the small rainfall entirely insufficient, frequent working of the ground enables the western to entirely dispense with irrigation.

It is said that margin of tillable land, east of the Rocky Mountains, is constantly extending westward. It is by no means certain that the rainfall is increasing; is not this result due then to increased tillage?

SIGNAL SERVICE THUNDERSTORM STUDIES.—These studies are persistently carried on by Professor H. A. Hazen, as may be judged by the following extract from the latest *Monthly Weather Review* (August, '86.):

"During August there were received from voluntary observers 631 reports of distinct storms; from Signal Service observers 337; and from special thunder-storm observers 1,884, making a total of 2,852, or 470 more than during June, and 144 more than during July. The distribution by states and districts will be seen in the accompanying table. This table does not give an idea of the relative frequency in the different states, as some have many more observers than others, but it will serve for comparison with similar tables in previous months. The days of greatest number were 1st, 219; 11th, 203; 12th, 238; 13th, 273; and 16th, 298; and of least number, were 2d, 19; 3d, 12; 7th, 14; 19th, 17; 20th, 18; 24th, 6; 25th, 17; 26th, 13; and 31st, 18. It will be seen that there were two well-marked periods of thunder-storm activity, from the 11th to the 17th, and from the 27th to the 30th. On the 16th the conditions were specially interest-

ing, it being the hottest day of the month, the temperature rising to 104° in the afternoon. On this date there were the most storms of any day, and some idea of the conditions on this date may be gleaned from the chart. Most all the storms on this date occurred before noon, hence the map of isobars, isotherms, and wind-directions has been chosen for 7h.00. It will be seen that, as in the previous month, nearly every storm is in the southeast quadrant of the low area. This chart is specially interesting as showing the conditions ushering in the tornadoes of the afternoon of this date, elsewhere described in detail."

The work must require an immense amount of clerical labor and we may expect very valuable results from it. The Service carries on at the same time series of electrometer readings at a limited number of stations. These are in thoroughly competent hands. The readings at Boston for August are discussed by Professor T. C. Mendenhall.

SEA-BREEZES AND NORTHERS IN SOUTHERN CALIFORNIA.—A circumspect paper in the ninth biennial report of the California State Board of Health, gives much information concerning the climate and diseases of southern California. The following account of the winds is of general interest, and is reproduced in the words of the author.

The prevailing winds of this region are generally called "trade winds." This name may answer for want of a better one, but, as a matter of fact, the upper and prevailing currents of air have more the nature of monsoons than of trade winds. During the winter months the prevailing winds are from the south and southwest; during the summer months, from the north and northwest. As a general thing, local winds assert themselves all over this part of the state, and, in fact, throughout the Pacific coast. Thus along the coast the land and sea breezes are nearly always to be found. They are very noticeable at Santa Barbara, Santa Monica, and San Pedro, perhaps less so at San Diego. During the very hot days in the interior, a stiff sea breeze all along the coast blows inland to replace the rising current of hot air. As a result, there is not only cool weather along the coast,

but the temperature of the inland belt is considerably modified. This is shown in comparing the temperature of the region west of the great divide with that east of it. In the former the temperature rarely reaches 90° Fahrenheit, while in the latter it frequently ranges from 115° to 125° for days at a time.

Another health-giving, but extremely disagreeable wind, is the "Santa Ana," or "norther." This is a hot and very dry wind, usually confined to limited localities a few miles inland, but occasionally sweeping over a broad belt of country. During the progress of this wind the air is highly electrified. Horses' tails stand out like thick brushes, the hair of the head crackles sharply when rubbed with the hand, and metallic bodies resting on an insulating material, such as dry wood, discharge themselves with visible sparks when a conductor is brought near. In one instance, it is said, the telegraph line between Los Angeles and Tucson, some four hundred and fifty miles in length, was detached from the battery and operated by the earth currents alone. After the clearing away of one of these wind storms, the atmosphere becomes wonderfully clear, pure, and invigorating.

In general, the direction of the local winds of the interior is governed, to a great extent, by the direction of the mountain ranges and the various passes. Thus the "Santa Ana" wind receives its name, because it frequently issues from the Santa Ana pass.

AGRICULURAL METEOROLOGY.—In the last annual report of the commissioner of agriculture, Mr. Colman suggests the establishment of a signal service station in connection with each agricultural college or experimental station, "for the routine work of the signal service and for special observation, under the direction of the college or station, for investigation of meteorological conditions affecting the health and growth of plants."

This is an excellent recommendation, but does not go far enough. The labors of such an observer would be very varied. He would not only have to attend to the regular observations and the questions of climate, but he should also be a teacher. The principles of modern meteorology should be included in the

curriculum of every agricultural college, and an acquaintance with it should be required of every graduate. So much of a farmer's success or failure depends on climate and weather that it is surprising that the agricultural colleges have not long ago made the knowledge of them compulsory on every graduate.

The observers, recommended by the commissioner, should therefore be professors, but they should be still more than this; they should be capable experimenters and investigators. There is a large class of problems which should fall under their care, and the investigation of them would require much knowledge and skill. Insolation plays a very important part in the development of animals and plants; questions of the sun's rays, their quantity and action, their variations in the different hours and for different states of the sky, the relative effects of the different elements of a solar ray, are some of the problems to be referred to such a professor. There are very many questions of the differential distribution of temperature and humidity—differences in sun and shade, on hill and in valley, in forests, and on ploughed land, on meadow, and many others,—which play a very important part in plant life and should be studied, and the results taught. The entire field of evaporation is even more important to the agricultural meteorologist than to others; and the moisture in the soil, how to measure it, how to conserve it or how to promote its evaporation, makes an important and almost unexplored field. The broad problems of climate are elucidated but the farmer also wants the perturbations due to topography and other sources. The relations of individual species to the individual meteorological elements are very incompletely known for even wheat and maize; for instance, who could tell what effect an increase of relative humidity has on wheat. But the problems which would fall in the province of such an official are very numerous, and we will not attempt to specify farther. What we wish to do, is to show that such an official as Commissioner Colman recommends would, to be successful or even useful, require a high order of learning and skill.

Krakatoa Again.—Some troublesome questions in regard to the volcanic theory of the red sunsets remain, and these are con-

sidered by Professor Keissling in a recent paper. The first is: Is it reasonable to think that the smoke and other material, sent by the volcano of Krakatoa into the air, could have moved around the earth in so short a time?

Professor Kiessling says that it is reasonable on a principle deduced by Mr. Werner Siemens whereby it can be shown that the upper layers of the air must lag behind in the rotation of the earth, and the equatorial masses at some elevation must have a westerly velocity of 276 feet per second, relative to the earth's surface, if the friction be not considered. This is equivalent to a velocity of upwards of 4,500 miles per day, or a completion of the equatorial circumference in between five and six days. The introduction of friction would reduce this velocity, and Professor Kiessling, after a careful collection of observations, finds actual velocities of about half the theoretical; that is the clouds would pass around the earth in less than a fortnight.

A second question is: Could the volcano emit a sufficient quantity of matter to produce such great effects? In reply we must recall the minute state of matter recently investigated. A heated body gives it off in great quantities, measured by its effects in making clouds, yet the body may not lose appreciably in weight. The particles are beyond microscopic reach but do not seem to be molecular. With Krakatoa, then, it is not the quantity of matter but the state of division which must be considered. It is experimentally proven that an infinitesimal portion of matter may, in the proper state, be productive of much cloud by the deposition of water on its minute dissociated particles.

Again: Could these particles have been suspended in the air for years? Certainly, for a very minute particle falls in air at ordinary pressures only at the rate of 0.1 of an inch per minute. Now these particles were elevated to a height of twelve or more miles, but even then they would fall only 0.4 inch per minute, and this rate would bring them to the ground, in still air, in from four to eight or ten years.

YELLOW FEVER OCCUPYING NEW TERRITORY.—For some reason yellow fever has never been known until recently on the west coast

of Mexico. It seems to have its home on the Antilles, and for a century or more, it has existed along the shores of the Caribbean Sea and the Gulf of Mexico. It has also been long known in Panama but it was not until 1882 that it came north to the cities of the west coast in Mexico. In that year its fatality was very great in Mazatlan, Guaymas, and other places, and since then it has appeared every year in these places, so that it may now be considered endemic.

Having passed up the coast to the northern Mexican states, there seems to be no reason why it may not go farther. The disease originates in a temperature above 80°, and flourishes in any temperature above 70°. Below 70° it declines and at 62° it cannot be propagated. Now the summer temperature of the western part of the United States is above 70°. Nearly all of the interior of California lies in the region of average summer temperature above 70°. The isotherm of 70° runs inland parallel to, and not far from, the coast, and leaves the state on the eastern side only at about the latitude of Cape Mendocino. This would make the western and northern limits of dangerous epidemics of yellow fever; the eastern limit would be formed by the dry region of Nevada and Arizona, perhaps pretty well east, for the disease stands considerable dryness. The climate of Spain and Portugal is relatively dry, but yellow fever has ravaged these countries several times.

The greater part of the Sacramento and San Joaquin valleys are quite as favorable for the propagation of the disease as the Lower Mississippi valley. Steamships and railroads put California in very direct communication with the Pacific Mexican states, and now that the fever has appeared in these states, the danger to California is imminent; indeed, an occasional case of yellow fever has already been imported into San Francisco. Yellow fever in the great interior valley of California would do incalculable damage to the state. Fortunately, as can be learned from the biennial report of the State Board of Health, the danger is well understood, and a vigorous quarantine was exercised during the last season.

Yellow fever is endemic in Rio de Janeiro, and in other Bra-

zilian ports. It has appeared in Venezuela, Guiana, Argentine, Ecuador, Peru, Columbia and the Central American states. It has also been epidemic in England (Southampton and Swansea), in France (St. Nazaire), Portugal, Spain and Senegal. It has been known in twenty-eight of the United States and has even reached Canada. It is said to never climb above an elevation of six hundred feet in the United States. This experience seems to be peculiar, for in Jamaica, on the Blue mountains as it has reached the altitude of three thousand feet. During the Mexican epidemic in Mexico in 1882, it reached Colima at an elevation of two thousand feet. In Peru it has reached Arequipa (7000 feet), and even Cuzco (11378) feet. In the latter place it committed fearful havoc, and finally got far up the Andes, 14000 feet above sea level. Its climbing power, even in dry countries, is great and no one can tell what elevation it may reach in California, if it once gets a foothold there.

COMPOSITE PORTRAITURE OF THUNDERSTORMS.—Professor W. M. Davis is very ingenious and suggestive in the application of graphic methods in meteorology. Graphics are so abundantly used in this science that it may almost be said of it, as of Geography, that it is a graphical science. Yet Professor Davis's suggestions have the charm of both novelty and promise, as the following shows, (taken from the proceedings of the American Academy):

"Three observations a day are sufficient to define the slow weather changes of the large cyclone storms; but in thunderstorms observations should be taken every fifteen minutes at most, that is, at the rate of ninety-six times a day, so rapid is the motion of these storms in comparison to their size. A simple method of portraying a storm, thus observed at numerous stations, would be the construction of synchronous maps of all elements: thus the storm as a whole is seen passing over the country. But even then it is not easy to bring all the details of many maps into a single mental picture; and, moreover, the unfortunate lack of observations must for sometime yet make these separate maps very imperfect. Some method of

composite portraiture is needed that shall throw all the observations into their proper position with respect to some controlling line, such as the storm-front, and at the same time allow the records of one station to supply the deficiencies of another. I have attempted to accomplish this in the following way. The attitude of the storm-front (rain-front) is first determined by charting all the times of rain beginning, and drawing lines to show the position of the front for every even quarter of an hour; the direction and velocity of advance are also thereby determined, and generally, in the best developed storms, a certain line may be chosen to represent the middle path of the storm: the average line of rain-front and the middle path are taken as axes of co-ordinates; time intervals before and after the rain beginning serve as abscissas, while distances north and south of the middle path are ordinates: and the ratio of abscissas to ordinates is known as soon as the average velocity of storm progress is determined. The axes thus chosen are drawn on a sheet of tracing-paper: now if this sheet be laid upon a map of the region traversed by the storm, and moved along in the direction of the storm's advance (the line of middle path being co-incident on the two), it (the tracing paper) may be taken as representing the storm stratum on its way across the country: every station that furnishes a record may be imagined to trace a line on the storm stratum about parallel to the middle path, and intersecting the rain-front to one side or the other of the middle path, at a distance from it measured by a positive or negative ordinate; and all observations can be placed somewhere on the lines thus traced, their distance in front or behind the rain-front being measured by positive or negative abscissas. In practice, a simple method of proceeding is adopted: lines are drawn on a storm stratum (tracing-paper) to represent the path of every station through the storm, and the name of the station is written at one end of its line: then a time scale is prepared to measure the abscissas, its unit being the average distance traversed by the storm in an hour; for a storm moving from west to east, as is the general rule, the scale is numbered from right to left; it is next laid on a certain station line, parallel to

the middle path, and placed so that the line of rain beginning for this station falls on the rain-front line; then all the observations from that station can be marked down opposite their proper hour and minute on the time scale, and they will thus fall in their proper place in the storm. After plotting a good number of reports in this way, the composite portrait shows that the area an hour or so in front of the rain is occupied with records showing high temperature, clear sky with clouds from which thunder is heard rising in the west; gentle winds, as a rule from a southerly quarter; nearer the storm the clouds cover more of the sky, and the temperature falls a little; close in front of the rain the wind-squall appears, blowing out from the storm; as the rain is reached, the wind dies away, the temperature falls rapidly, the thunder grows louder, and lightning strokes appear; half an hour or more, with rain still falling gently, the western clouds break up, and blue sky appears; the temperature rises slowly, and the thunder dies away as the storm moves off; and rainbows appear on its back as the sun shines out. It soon becomes evident that there is really a systematic distribution of certain elements of the storm that are susceptible of legitimate averaging; and from their graphic representation in the composite portrait, the proper areas and intervals for averaging may be chosen. In this way, the fullest use may be made of the most varied records.

Annual Meeting of the New England Meteorological Society.—The third annual meeting of New England meteorological society was held at the Institute of technology, Boston, Oct. 19. Prof. J. D. Whitney read a paper on 'Rainfall statistics in the United States,' considering especially the statements that have been made concerning the increase of rainfall on the western plains as a result of the cultivation of the ground. These statements are considered altogether untrustworthy. In dry regions the amount of precipitation is generally variable by a considerable percentage of its annual value, and the records as yet obtained from the west are seldom of long enough period or of sufficient accuracy to decide so important a question as

that of permanent change in the annual fall. Special mention was made of the want of uniformity in the placing of gauges: under the military regime, they were placed eight feet above the ground; the Smithsonian rules call for an elevation of only six inches; the Signal Service gauges are at all heights up to one hundred and sixty-two feet.

Mr. S. A. Eliot read an essay on the Relations of forest to rainfall and water supply. The common opinion that forests increase and clearings decrease the rainfall was traced to the authority of eminent writers, based not on well-kept observations of rainfall under these contrasted conditions, but chiefly on the well-known diminution of stream-flow in cleared districts. This, however may be due to increased evaporation rather than to decreased rainfall. Forests undoubtedly retard evaporation of fallen water, but it is very problematic if they increase the amount that falls.* Mr. Fitzgerald commented on this by referring to a statement, apparently on the authority of De Lesseps, that the rainfall along the Suez canal had increased since trees were planted there. On writing directly to De Lesseps, answer was received that he had made no such statement, and that there were no facts to support it.. Mr. Davis added, that, if the causes controlling rainfall be separated into those dependent on and independent of forests, we find that the latter are now powerless to produce forests in forestless countries, such as those around the eastern Mediterranean, and therefore could not have originated the forests once there, unless formerly of different value from now; but, if it be admitted that these non-forest causes vary, the deforesting may be due to natural changes, not to the hand of man.

Several seismoscopes and a series of photographs illustrating the effects of the Charleston earthquake, lent by the geographical survey, were exhibited at the meeting. The seismoscopes were briefly described by Prof. Holman; their construction is relatively simple, and they are designed for distribution to a number of stations throughout the country, so that the time of

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*These papers will be published in later numbers of the JOURNAL.

the occurrence of earthquake shocks can be definitely recorded. Mr. Davis called especial attention to the photographs of the so-called "craterlets" formed by outbursts of water in the district about Charleston: they were generally misapprehended in the newspaper reports and ascribed to volcanic action; but there is little doubt that they were very superficial phenomena caused by the passage of a wave of compression through a waterlogged stratum near the surface; the water being relatively incompressible bursts through the overlying layers, and carries sand and clay out with it.

In the absence of the director, Professor Upton, who will spend the coming year in Europe, an informal report on the Society was presented by the secretary. Members now number 110, against 95 last year, and include several well-known meteorologists outside of New England. The monthly bulletin has been regularly issued, and recent numbers include reports from 140 to 151 observers, against 123 last year. Several observers on the White Mountains have boen supplied with instruments by the Appalachian Mountain Club. In certain districts, a further increase in the number of observers is not desired, so that more attention has been devoted to improving the character of the observation than to increasing the number of stations. About five hundred volunteers took part in the observations of thunderstorms during the past summer, but owing to the variety of storms, the season's work has not been so successful as was hoped. Free test of instruments belonging to observers reporting to the society have been begun by Prof. S. W. Holman. Three valued observers have been lost by death,—Hon. Hosea Doton, Woodstock, Vt.; Dr. B. F. Harrington, Wallingford, Conn.; and Mr. R. H. Gardiner, Gardiner, Me. The records of the last two will be continued. Special investigations, supported by grants from scientific funds, have been undertaken: a report on thunderstorms in New England in 1885, by the secretary, is thus already distributed to members; and a report on the distribution of rain in cyclonic storms, by the director, is now in course of publication in the American Meteorological Journal. While such special studies are generously supported, the society

still needs to increase its membership for the support of its regular work.

The former council of the Society was re-elected, with the addition of Mr. A. Lawrence Rotch, of the Blue Hill Meteorological Observatory.

A CONNECTICUT TORNADO.

GENERAL WEATHER CONDITIONS.

The general weather conditions over the Eastern States as shown by the Signal Service Weather Map of September 12, 1886, at 7 a. m., were as follows: An area of low pressure, elongated towards the southwest, was central north of Lake Ontario, with moderately steep gradients for south to southwest winds which prevailed in New England and New York. In the Upper Lake region the winds were west, the line of minimum pressure marking this change in direction. The weather was cloudy or fair in New England and down the coast, but light rain was falling in the Lower Lake region. The temperature was slightly above the normal in New England, the isotherm of 60° passing north of Portland, and south of Albany. The temperature was much lower where the winds had shifted to west, the isotherm of 40° passing near Escanaba and St. Paul.

Reports from stations in Connecticut and adjacent states give these data concerning the weather of September 12th. Cloudiness began to increase in the morning with a falling barometer and a rising temperature and humidity. Rain began between 5 and 7 p. m., accompanied in some places by thunder and lightning, and lasted till nearly the next morning. The maximum temperatures were not unusually high, not exceeding 80° at any of the stations, but the high humidity made it seem warmer. There was no marked change in temperature, beyond the usual diurnal fall, until after midnight of the 12th. Providence, R. I., records show the lowest pressure to have been reached about 10 p. m., followed by a sudden veering of the wind from southwest to northwest. At Blue Hill, Mass., there was a rapid fall of temperature from 67° to 58° between 10:30 and 11 p. m., accompan-

ied by a sudden veering of the wind from south to northwest, following the lowest pressure of 29.6.

The Weather Map for 7 a. m., of the 13th shows the area of low pressure to be central in the Gulf of St. Lawrence and a high area covering the Middle Atlantic States. The weather was clear in New England and fair in the Lake region with west winds. The temperature had fallen several degrees in New England and New York, the isotherm of 60° now passing south of New London and New York and that of 50° through the Lower Lakes.

SCENE OF THE TORNADO.

Burnside village is situated on the left bank of the Connecticut, on a level plain about four miles east of Hartford. A river emptying into the Connecticut, flows through Burnside and the track of the tornado after crossing the river was along its right bank.

ACCOUNTS OF EYE WITNESSES.

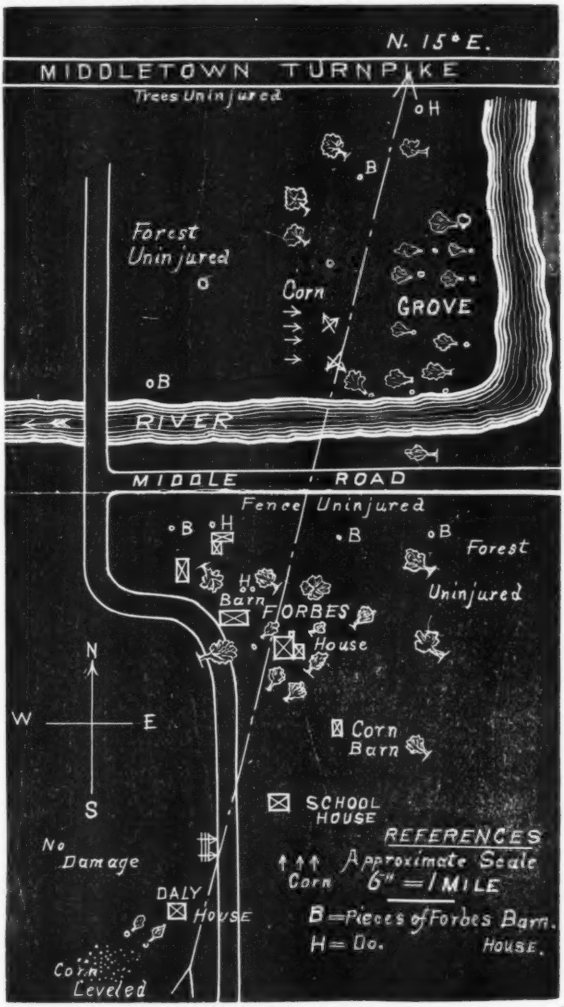
For several days the weather had been sultry with fogs in the mornings. On Sunday, the 12th, the wind blew from the southwest and about 6 p. m. dark clouds began to appear in the southwest and southeast, and distant thunder was heard. All the evidence fixes the time of the tornado at a few minutes before 7 p. m., at which time the wind appears to have been southeast. The tornado first made its appearance about 2¼ miles southwest of where it first struck the ground, as a very black cloud with its end elevated above the earth and revolving in a direction contrary to the clock hands. One person speaks of the cloud as turning over and over vertically, which may have been merely the effect of the position of the observer. A roaring, described like the noise of a train of cars, accompanied the passage. As no exact times were noted its rate of progression cannot be determined, but accounts agree in stating that it was over in a moment. The lightning and thunder were reported as sharp by some and faint by others. At Hartford, four miles west, and Manchester five miles east, distant thunder and lightning were observed in the direction of Burnside. Heavy rain is said to have begun before the tornado and to have continued some time

afterwards, with light rain during the evening. There is no evidence that hail occurred. The temperature seems to have fallen slightly after the passage of the tornado, but the change was probably not great.

AN EXAMINATION OF THE TORNADO'S TRACK.

This was made three days after its occurrence, before the debris had been much cleared up. The approximate course of the tornado was found to be N. 15° E. The accompanying diagram will be referred to. The tornado first struck the earth near the Daly house. Corn was prostrated here and a few branches lay toward the northwest, broken evidently by the rear wind, the strength at that time being small. A little to the north, apparently directly in the tornado track, a school house, and more to the northeast, a light corn-barn, were uninjured. Mr. Forbes' house, a quarter mile north of Daly's, is a solid two and a half story frame house, forty feet square. The south end of the gable roof with the chimney was blown off and the house moved east on its foundations two inches. There was no twisting apparent and the house seems to have lifted and dropped back again. An addition on the west side, lower than the main house, had all the tin stripped from the roof. A twisted piece several feet square was found a half mile north, and same was said to have been carried a mile. The porch on the north end was blown away and a piece found behind the barn, 200 feet northwest, could only have been carried there by being thrown out from the top of the funnel cloud. On this side of the house windows not protected by blinds were broken. As the centre of the tornado seems to have passed between the house and the barn, further damage from the expansion of the contained air may have been prevented here by the fact of the door being open. Fowls were killed and one was said to have been plucked, possibly by the expansion of the air in the quills. The barn, 200 feet northwest of the house, had the east half of the roof and part of the south side torn off. The force of the wind may be imagined from the breaking of a 9x9 inch roof timber. The position of a scantling from the barn, 300 feet northwest of it,

behind a tree and a barn, can only be explained by supposing that it was thrown out from the top of the tornado cloud, and



other pieces found several hundred feet northeast, must have been similarly carried. Shingles found in the track of the tor-

nado, half a mile northeast, seemed to have conveyed there by the forward motion of the tornado. In front and in rear of the house apple trees were splintered or uprooted, in some cases being moved fifty feet northeast and covered with mud. These probably withstood the first blast but succumbed to the stronger rear wind. Some trees near the barn, lying northwest, must have been near the centre of the tornado. Across the road west of Forbes' an oak tree some four feet in diameter at the base, lay uprooted towards the northeast, while just north, the trunk of another oak nearly as large but somewhat rotten was broken in two and lay to the southeast. This tree stood in the yard of a house which was in no way damaged. These trees marked the west, or left hand edge, of the tornado track, which was here about one thousand feet wide. On the east, or right hand edge, the trees fell towards the northwest, showing distinctly the effect of the winds rotating contra-clock wise.

Beyond the Middle road the land falls away to the river. Little or no effect was seen here, the fence along the road running east and west being intact. Across the river, however, quarter of a mile north of Forbes' there was great destruction of forest trees in a grove. Almost every tree, some of them two feet in diameter, was cut off twenty feet from the ground, the tops invariably falling towards the west. This marked the right hand side of the tornado, which, as might be expected, was the most violent, the progressive motion of the storm being here added to its rotary motion. In a cornfield to the west, the cornstalks lay piled on each other in all directions, those on top pointing north showing the effect of the rear blast. Further west the corn lay mostly east. This marked the left hand side of the track, which track was here about six hundred feet wide. A few uprooted apple trees south of the Middletown pike, lying northwest (the same as the first ones struck) marked the end of the destructive path of the tornado here, which was about a mile in length. It was reported to have afterwards descended in Ellington and Windermere, ten miles northeast of Burnside, and damaged orchards and a barn, but beyond this nothing more was heard of it.

The writer is indebted to Mr. H. Helm Clayton for assistance in tracking this tornado.

CAUSE OF THE TORNADO.

The cyclone in the northeast caused inflowing warm and moist southwest winds, while the colder west winds in the rear accompanied an anti-cyclone. At the line of meeting it may be supposed that the colder westerly winds flowed over the warmer southerly, making the equilibrium unstable, which was the condition over New England on the afternoon of September 12th. To quote from Prof. Davis' lucid explanation of the formation of a tornado in his little book on "Whirlwinds, Cyclones and Tornadoes:" "The warm air feeling about for a point of escape through its cold cover, soon makes or finds a vent where it can drain away upwards; and then the entire warm mass, even a mile or more in diameter, and often more than a thousand feet in thickness begins the rotary motion, rises at the centre and passes away. * * * * As a result (of the centrifugal force) most of the central air must be drawn out by friction into the whirling cylinder and prevented from returning by the centrifugal force. The core will be left with a feeling of emptiness like an imperfect vacuum. If there were air near by not controlled by the centrifugal force, it would rush violently into the central core to fill it again. * * * The lowermost air is prevented (by friction with the ground) from attaining the great rotary velocity of the upper part, consequently, is much less under the control of the centrifugal force which is measured by the square of the velocity. The surface air is, therefore, just what is wanted to fill this incipient vacuum; so it rushes into the core and up through it with a velocity comparable to that of the whirling itself; and this inward rushing air is the destruction surface blast of the tornado. * * * * An inclosed mass of air, as in a house, suddenly explodes as the vacuum is formed over it, and as the air rushes to the centre and then expands and cools, the vapor becomes visible in the great funnel or spout, pendant from the clouds above. No rain can fall at the centre. Bodies much heavier than rain are lifted there instead of dropped, so the rain must rise through the central core and fall to one side of the

storm, or before or behind it. If the expansion be very great and the altitude reached by the drops rather excessive, then they will be frozen to hail storms before falling. Hail storms and tornadoes commonly go together; they mutually explain each other. Electricity has no important part to play in the disturbance. * * * The progressive motion of the tornado is the result of its bodily transportation by the prevailing winds (here southerly the track of the tornado was nearly north) and the tornado lasts until the lower warm air which constitutes the original unstable mass is exhausted."

It should be noted that the condition that the air should be moist as well as warm was fulfilled. This is important in the generation of a tornado, since, as the air rises it expands and cools, but in doing so it condenses some of the contained vapor, thereby setting free its latent heat, with a result that the ascending column of moist air will not be allowed to cool so fast as if the air had been dry, and the equilibrium is maintained unstable longer. The peculiarities of the Burnside tornado were the absence of hail and the slight fall of temperature after its passage. As before stated the tornado occurred some time prior to the minimum pressure or the change in direction of the wind.

A. Lawrence Rotch.

October, 1886.

AN INVESTIGATION OF CYCLONIC PHENOMENA IN NEW ENGLAND.

CONTINUED.

Before specifying the results obtained from Table II, (See page 264, October No.) two other tables are presented which contain the results of a further investigation upon the times of beginning and ending of precipitation, in order to group together the conclusions of this section. These tables are designed to show the progression of the front of the precipitation and also of its rear, within the limits of observation. The data are more meagre for this investigation than for the preceding, for it requires time observations made not only at a given group of

stations, but all along the district. As it usually, for example, begins to rain about eight hours later in eastern Massachusetts than at the western boundary of the state, when the progression is easterly, it often happens that observations at one extremity are in the night. This added to the inherent difficulty of all observations of the time of beginning and ending of precipitation is the cause of the omission from the tables of some storms altogether, and numerous omissions in those that are included. The headings of these tables may need some explanation. The phrase "Geographical Area" denotes that portion of New England over which the observations are sufficiently abundant to be used for this purpose. On the maps containing these records, lines were drawn showing the places where it began (or ceased) to rain or snow at the same time; the advance of these lines furnishes the means of calculating the rates given in the sixth column of each table. The "Interval in Hours" is the time elapsed between the earliest and latest of these isochronous lines. Thus in table III, No. 2, the data are confined to the state of Massachusetts, and the direction of progression was easterly. It began to snow near the western boundary five hours before it began to snow near the eastern, and the rate was about nineteen miles per hour. Columns four and seven give data for the movement of the centre of the cyclone corresponding to those given in the preceding columns for the precipitation front or rear, for purposes of comparison. The last two columns give the interval between the times of beginning or ending of precipitation and the arrival of the centre of the cyclone at its nearest point. It is twice reckoned; (a) from the earliest (b) from the latest of the lines of equal time. The difference in these two values is due to a difference in the rate of movement of the centre of the cyclone and the boundary lines of its precipitation. This may be due either to a widening or contracting of the precipitation area of the cyclone or to a change of rate of the cyclone after the precipitation had begun (or before it had ceased) and the time of its passage. The values of the rate of the cyclone and its direction are calculated for its position when the rain or snow was beginning (or ceasing) and, therefore, differ

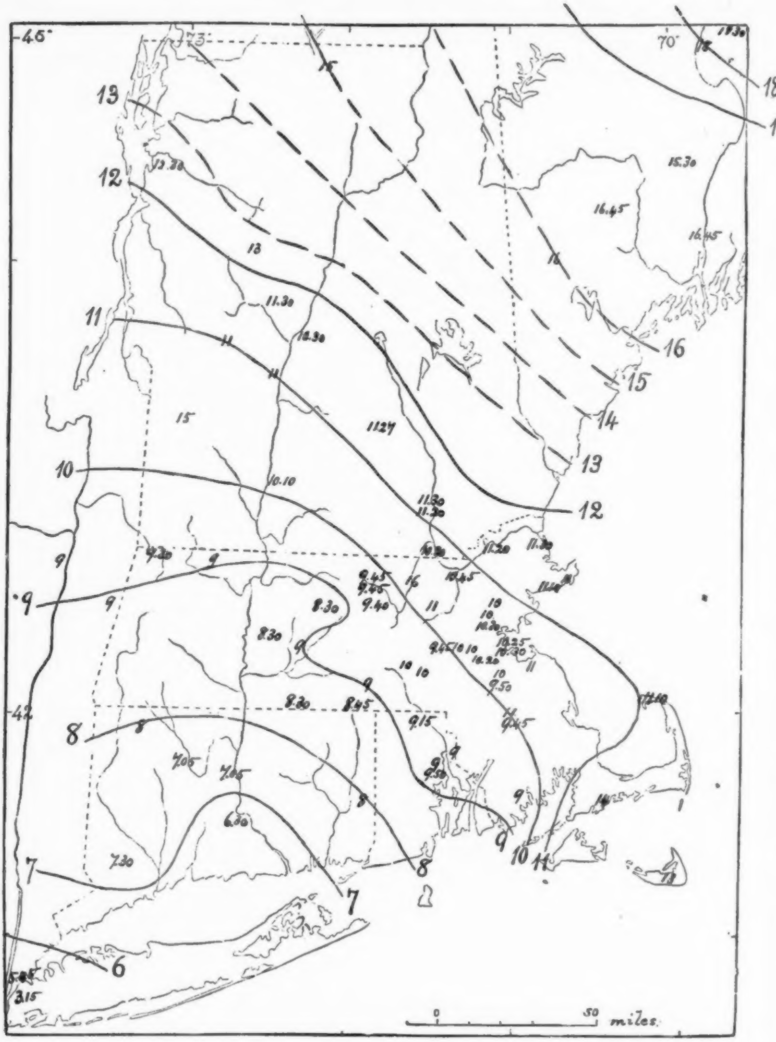


CHART III.—*Times of beginning of rain, October 13, 1885.*

The times are reckoned from 0 to 24 hours, midnight to midnight; that is, afternoon hours are the usual times increased by twelve. Lines of equal time are drawn for every hour The broken lines are uncertain because of the lack of observations.

from those previously given in Table I and Chart I. In order further to illustrate this subject, Chart III is given, which represents the progression of the time of beginning of rain on Oct. 13, 1885, storm No. 20. Similar charts for Nos. 7 and 17 are given by Prof. Davis in his paper on Thunderstorms of 1885, above referred to.

TABLE III.

Relation of the time of begininng of the precipitation to the position of the centre of the cyclone.

No.	Geographical Area.	Direction of motion of prec. front.	Direction of motion of cyclone.	Interval in hours.	Hourly rate prec. front. (miles)	Hourly rate of cyclone. (miles)	Interval before arrival of cyclone. a (hours)	b (hours)
1	Conn., Mass , R. I.	N. E.	N. E.	3	56	20	42§	43§
2	Mass.	E.	E.	5	19	41	9	6
3	Eastern Mass.	....	E.	....	....	26	11	....
5	Eastern Mass.	....	E.	....	....	....	....	....
6	....	N.?	E. S. E.	....	....	30	....	....
7	Eastern Mass.	....	E.	....	....	22	15	....
8	Vt , Conn., Mass., R. I.	E.	E.	7	34	24	20	23
9	Eastern Mass.	....	E. N. E.	....	....	24	-5*	....
12	Whole area.	N. N.E.	N. E.	8	38	28	13	8
13	Eastern Mass.	....	E.	....	....	29	17	....
14	Eastern Mass.	E.?	E.	....	....	33	10	....
17†	Vt.. Mass.	S. E.	N. E.	4	28	18	0	0
18	Whole area exc. Me.	N. E.	N. E.	12	15	25	26	20
19‡	Whole area.	S. E.	N. E.	23	11	36	5	....
20	Whole area	N. E.	N. W.	13	24	18	32	30
21	Eastern Mass.	S. E.	N E.	....	....	28	-12*	....

* The negative sign indicates that the centre had passed *before* the precipitation began.

† Reference is to the rain of July 9, 1885; there had been earlier showers.

‡ Reference is to the rain of Aug. 22, 1885; it had rained on the preceding day, the motion of the rain front having been easterly.

§ Precipitation began while the cyclone was developing in the south-west.

TABLE IV.

Relation of the time of ending of the precipitation to the position of the centre of the cyclone.

No.	Geographical Area.	Direction of motion of prec. rear.	Direction of motion of cyclone.	Interval in hours.	Hourly rate of prec. rear. (miles)	Hourly rate of cyclone. (miles)	Interval after passage of cyclone. a (hours)	b (hours)
1	Conn., Mass.	N. E.	E.	4	35	40	-2*	-1*
6	Vt., Mass.	S E.	E.	14	11	15	12	17
9	Vt., Mass., Conn., Me.	S. E.	E.	12	8	24	3	12
11	Mass., Conn., R. I.	E.	S. E.	10	10	38	-15*	-13*
14	Eastern Mass.	....	E	....	....	27	5	....
16	Eastern Mass.	E.	S. E.	....	....	9	....	....
18	Eastern Mass.	N. E.†	N. E.	....	....	28	-4*	....
20	Eastern Mass.	N. E‡	N. E.	....	....	35	8	....
21	Whole area.	S. E.	N. E.	12	21	28	11	23

* The negative sign indicates that the precipitation ceased *before* the passage of the cyclone.

† Progression was north-easterly from Long Island to north-eastern Massachusetts, with later rains in Vermont.

‡ Data indicate a north-easterly progression but are too meagre to determine the rate.

The conclusions derived from the above investigation may be summarized as follows:

1. The characteristics of the storms under discussion, as far as relates to their precipitation, are largely peculiar to each storm. This is seen in the amounts of the precipitation (Table I.) its distribution (description of each storm and Table II.) in the relation of the position of the storm centre to the times of beginning and ending of rain or snow (Table II.) and in the rate and direction of these times (Table III.) Limiting values and averages can be derived from these tables of the several characteristics, but they would have only an approximate value, on account of the small number of storms examined. The prominent individual features have already been mentioned; others can be derived from an inspection of the tables. There are, however, certain indications of common features in these storms which it may be well to note, with the caution that they depend upon very few storms.

2. In each of the northern group of cyclones, seven in number (No. 10 not discussed as explained above) the maximum area, with two exceptions, (one of which is doubtful) is south of the path of the cyclone, and sufficiently removed from it to indicate a decreased precipitation at the storm path (Table II).

3. In each of the southern group, four in number, the maximum area is north of the storm path (Table II).

4. In each of the group, Nos. 17-22, in which the cyclone moved far north of the district, the maximum area is far from the centre towards the southeast (Table II.). This of course does not indicate that the real maximum of the storm itself was southeast of the centre, for the observations are all far south of the storm path, but it does show that the precipitation does not diminish uniformity from the path southwards, but that there are maxima south of the path.

In order to illustrate these facts further, two charts are here given showing the position of the precipitation line which is 0.8 of the maximum, the approximate position of the maximum point itself (indicated by the letter M), and the position of the line of minimum precipitation noted. This is a dotted line and is usu-

ally 0.1 or 0.2 of the maximum precipitation. Chart IV is for the northern, Chart V for the southern group. In constructing them, the arrow was drawn upon tracing paper, and then carefully placed over the track of each storm in turn, care being

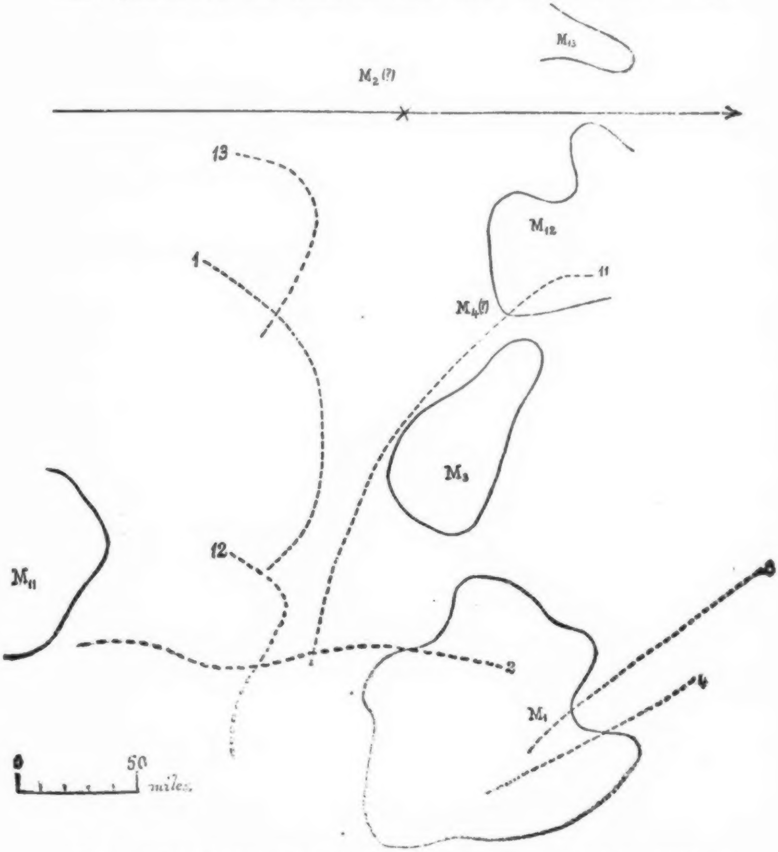


CHART IV.—*Combination chart for northern group, showing relation of maximum and minimum areas of precipitation to path of the cyclone.*

M denotes position of maximum area, the subscript, the current number of the cyclone; the full lines, the region where the precipitation was 0.8 of the maximum; the dotted lines the region of minimum precipitation, usually 0.1 or 0.2 of the maximum. The figures adjacent to the lines are the current numbers of the cyclones.

taken to have the point marked x centrally located in longitude. The subscripts and figures adjacent to the lines, denote the number of the cyclone in this paper. The values given in Table II, columns two and three, were derived from these charts. From these charts an additional fact is shown.

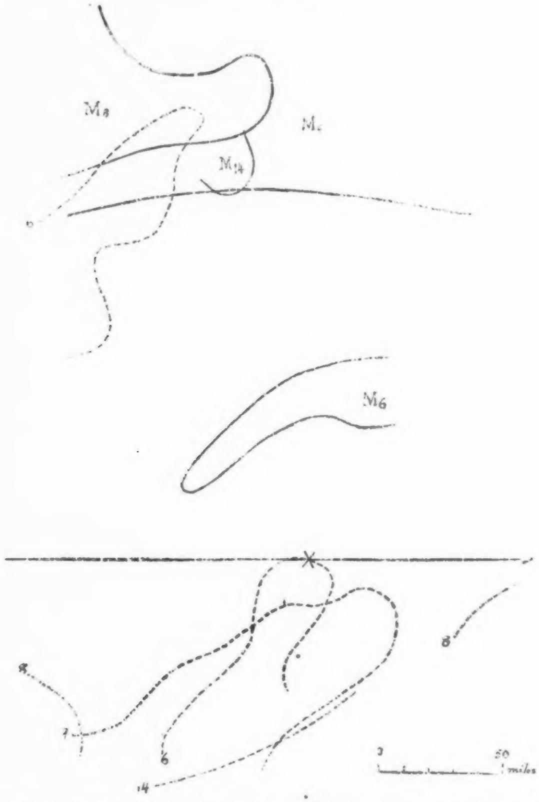


CHART V.—*Combination chart for southern group, showing relation of maximum and minimum areas of precipitation to path of cyclone.*

[Symbols as in chart IV.]

5. The minimum lines of the southern group lie very near the storm path on the southern side, averaging about fifty miles

from it. In the northern group, they are further removed from the path. In both cases they lie near the southern coast, the limit of the district.

6. Superposing these charts upon a map of New England, with the storm tracks coincident with the average of the two groups, it has been found that the maxima of the two groups very nearly coincide, indicating that the greatest precipitation in both classes lies in the line of latitude extending across Vermont, New Hampshire and Maine, about 75 miles north of the Massachusetts boundary. The average maximum of the group, Nos. 17-22, lies in the latitude of central Massachusetts.

From tables III and IV, the following are derived:

7. The direction of movement of the front and rear of the precipitation generally coincides with that of the cyclone; there are however, marked instances of departure: one of these, No. 20, is probably only apparent as the cyclone was at the time of the beginning of the rain moving in an abnormal northwestern path, its general direction being northeasterly; the others, Nos. 17, 19, and 21, are summer thunder-showers, which it is well-known, often more at a large angle from the general direction of the cyclone within whose influence they form.

8. The rate of progression does not agree with that of the cyclone, as already pointed out. In the front of the cyclone, there are five instances in which the precipitation moved faster than the cyclone, three in which it moved less. In the rear of the cyclone all of the instances, five in number, show a slower movement of the precipitation, in two of which, Nos. 9 and 11, it is quite marked.

These conclusions close the discussion of the first division of the subject. Attention will now be given to those cyclones which approach New England from the south.

II. CYCLONES APPROACHING NEW ENGLAND FROM THE SOUTH.

The study of cyclones of this class has been pursued upon the same plan as that of the former class. The results will therefore be given in the same form. Several subdivisions might be made, according to the previous history of the cyclone, whether

it was generated within the limits of the United States, or entered it from tropical waters, or entered New England from the middle Atlantic ocean. These subdivisions were made in the investigation, but as the number of cyclones under discussion is small, they will all be considered in one division arranged chronologically, and the peculiarities due to their previous course mentioned as the investigation is described. The following table gives in condensed form the general characteristics of each cyclone. The headings have the same significance as in Table I.

TABLE V.

General characteristics of cyclone.

Reference No.	Date of passage.	Pressure at centre.* (inches)	Hourly Velocity (miles)	Precipitation.		
				Kind.	Max. am't. † (inches)	Duration. (hours)
23	Jan. 28, 1885.	29.5 d	54	Snow.	1.2	22
24	Mar. 15, 1885.	29.4 d	33	Rain and Snow.	1.2	....
25	Mar. 19, 1885.	29.3	36	Snow.	....	....
26	Apr. 4, 1885.	29.4 d	28	Rain.	1.5	....
27	Oct. 21, 1885.	29.8 d	33	Rain.	2.8	6
28	Nov. 2, 1885.	29.6 d	50	Rain.	3.7	8
29	Nov. 9, 1885.	29.5 d	45	Rain.	2.9	60
30	Dec. 31, 1885.	29.8 i	26	Rain.	1.9	15
31	Jan. 9, 1886.	28.7	31	Snow.	1.9	15
32	Feb. 15, 1886.	29.5 d	53	Rain.	0.5	1
33	Apr. 7, 1886.	29.8 i	....	Rain and Snow.	3.4	42
34	May 9, 1886.	29.5 i	26	Rain.	2.6	22
35	May 25, 1886.	29.3 d	19	Rain.	1.1	6

* The letters *d* or *i* indicate that the pressure was either diminishing or increasing during the passage of the cyclone over or near New England.

† The values in this column are the average of the three highest records reported.

The paths of the central depression in each of the cyclones which traversed New England have already been given in dotted lines upon Chart I. Those given are Nos. 23, 24, 26, 27, 28, 29, 30, 31 and 32; of those omitted No. 25 moved northeasterly in the Atlantic far from the coast, No. 33 turned easterly into the ocean in New Jersey, No. 34 moved northeasterly in the Atlantic about thirty miles from Nantucket, and No. 35, which developed east of New England, moved northeasterly along the Maine coast. A more detailed description of each cyclone will now be given.

23. Jan. 28, 1885. This severe cyclone developed in the west, moved southeasterly into Missouri, thence into the Atlantic from

New Jersey, and thence rapidly across the Atlantic in a northeasterly direction, occupying but three days for its ocean transit. It was increasing in violence as it passed New England. The precipitation was wholly snow, with its maximum amount in northern Vermont.

24. Mar. 15, 1885. This storm approached the coast from the ocean, and increased in violence as it passed over New England. Its precipitation was rain and snow, and distributed with a maximum in southeastern Massachusetts, not far from the central path.

25. Mar. 19, 1885. The precipitation in this storm was light snow at scattering stations. The storm itself was severe on the Atlantic, but moved too far from the coast (about 450 miles) to have much influence on the conditions over the land.

26. Apr. 4, 1885. This cyclone was formed in Colorado, moved southeasterly into Arkansas, thence northeasterly to Delaware and along the coast. The rainfall was abundant, and shows well defined maximum areas in Rhode Island and eastern Massachusetts, along the Connecticut river in Massachusetts and Connecticut, and again in northern Vermont. The rains were for two days, with times of beginning and ending not well determined.

27. Oct. 21, 1885. This was not a severe storm, but it increased in violence as it approached from North Carolina where it had formed. The rain was very heavy in northern Vermont, over two inches having fallen in the northern half of that state, but the amount diminished southeasterly to 0.1 inch at Nantucket.

28. Nov. 2, 1885. This cyclone moved rapidly from the North Carolina coast, and was attended by severe gales on the coast. The rainfall was very heavy, exceeding two inches along the Connecticut River in Massachusetts and Connecticut. Four inches fell in central Long Island and southern Connecticut. This large amount fell in the short time of fourteen hours. The region of heaviest rainfall corresponds closely with the path of the centre of the storm, and this is the only instance among the forty storms investigated in this paper where this is unmistakably the case.

29. Nov. 9, 1885. This cyclone entered Rhode Island from the Atlantic, and was preceded by rain for two or three days, which ceased as the centre passed. After leaving Newfoundland it journeyed leisurely across the ocean reaching the coast of Spain in nine days. The rains in New England exceeded two inches in central Massachusetts, southern New Hampshire and northwestern Connecticut. The continuance of rain for several days in advance of the storm possibly indicates its formation at the time, in the Atlantic near New England.

30. Dec. 31, 1885. This cyclone formed in Virginia and was not a severe storm. The precipitation was not heavy, except in a narrow strip along the Connecticut River in Massachusetts and Connecticut, where it exceeded 1.5 inches.

31. Jan. 9, 1886. This was a very violent storm, and exhibits the characteristics of a cyclone to the greatest extent of any storm in this class. It was also more severe than any cyclone investigated in this paper, with the possible exception of No. 13 already described. It was better situated for observation than the latter, and will accordingly be specially examined later on. It originated south of Texas, and moved along the coast with a pressure at the centre of only 28.7 inches. It lost its energy and was dissipated north of New England. The precipitation was snow irregularly distributed. See Chart VI.

32. Feb. 15, 1886. This cyclone moved with great rapidity from southern Texas where it was first observed; it passed wel[l] into the ocean before it was dissipated. The rains were of short duration, light, and not general over the district. The maximum amount, 0.5 inches, seems to be near the path of the storm in southern and central Vermont.

33. Apr. 7, 1886. This cyclone had a peculiar path. It moved from the northwest in a southeasterly direction to the Gulf of Mexico and then curving northeasterly, advanced rapidly towards New England with increasing energy. On reaching Delaware, however, it was checked in violence and ceased its movement; after lingering in New York state with its centre variously defined, it again developed sufficient energy to move on, and and entered the ocean from New Jersey, traveling easterly south

of Long Island. The rain and snow falling in New England were heavy, continuing for nearly two days. Over two inches were recorded at Connecticut stations and in northern Massachusetts and southern Vermont, and 3-4 inches fell in western Long Island, the nearest point to the abnormal movements above noted.

34. May 9, 1886. This storm came from Texas, entered the ocean from Virginia, and moved northeasterly passing not far southeast of Nantucket. The rains attending its passage were heavy especially in Massachusetts, Rhode Island, and Connecticut. The maximum area, exceeding two inches lies in the Hudson valley.

35. May 25, 1886. This cyclone seems to have originated in the Atlantic east of Massachusetts and developed some violence as it passed along the Maine coast. The rainfall was in the form of light showers on several days. The maximum area was along the southeastern coast, and also in northern Vermont, where a single station reports over two inches.

The foregoing description shows that while the storms of this class all approached New England in paths not widely divergent, they were quite different in their origin. Three, Nos. 23, 26 and 33, are examples of cyclones which enter the country in the northwest, or else are there formed, move southeasterly, then curve to the northeast. Sometimes these cyclones actually pass into the Gulf of Mexico, as was the case with No. 33, when they return to the country with redoubled energy. None of the cyclones enumerated are complete examples of those long-lived cyclones which form in tropical waters, move northwesterly to the Gulf of Mexico, curve slowly to the northeast, and then with increased speed move along the coast and across the ocean. Cyclone No. 20, entered the country from the West Indies but passed northwards to the lakes and thence northeastward, and has, therefore, been considered under the first-class. It will be noticed, also, that none of the cyclones of this class occurred in the summer months. This is the usual fact, though some are occasionally observed, especially in August.

The further study of these cyclones has been pursued on the

same plan as that already described in the preceding division of this paper. Tables VI, VII and VIII give in condensed form the results of this study, which are given without further comment. Their explanation is the same as that of Tables II, III, and IV, respectively.

TABLE VI.

Relation of the precipitation to the path of the cyclone.

No.	Distance of max. area from path. (miles)	Direction of max. area from path.	Distance of center at begin of prec. (miles)	No. of records.	Direction of centre at begin. of prec.	Distance of centre at end of prec (miles)	No. of records.	Direction of centre at end of prec.
23	250	N. W.	400*	7	S. W.	400*	7	N. E.
24	40	S. E.	....	....	....	....	....	....
26	120	N W.	366	26	S. W.	164	22	E.
27	100	N. W.	120*	11	S. W.	190*	6	N.
28	0	....	320*	8	S. W.	100*	29	N. W.
29	50	W.	....	....	....	110*	9	S.
30	30	N. W.	354	51	S. W.	102	23	S. E.
31	10	N. W	456	34	S W.	117	43	N N. E.
32	30?	S E.?	148	19	N.	173	17	N. E.
33	....	....	550*	23	S. W.	....	....	....
34	120	N. W.	470*	6	S. W	130*	6	S. E.
Average.	61	N W.	354			165		

* Determined from stations in eastern Massachusetts only.

TABLE VII.

Relation of the time of beginning of the precipitation to the position of the centre of the cyclone.

No.	Geographical area.	Direction of motion of prec. front.	Direction of motion of cyclone	Interval in hours.	Hourly rate of prec. front. (miles)	Hourly rate of cyclone (miles)	Interval before arr. of cyclone. a. (hours)	b. hours)
23	Eastern Mass.	....	E.	....	....	35	17	....
24	Vt., Mass , R I.	E. or S. E.*	N. E.	....	....	....	........†	7
26	Eastern Mass.	....	E.	....	....	9	19	....
27	Mass., R I	E.	N. E.	7	10	33	5	−1 ‡
28	Eastern Mass.	....	N.	....	....	50	6	....
29	Eastern Mass.	....	N.	....	....	........†	........†	....
30	Whole area, except Me.	E. N. E.	N. E.	8	16	29	10	8
31	Eastern Mass.	N. E.	N. E.	....	....	26	13	....
34	Whole area.	N. N. E.	N E.	18	18	18	26	21

* Data too meagre to determine more closely.
† Track in Atlantic and not charted.
‡ The negative sign indicates that the centre had passed before precipitation began.

TABLE VIII.

Relation of the time of ending of the precipitation to the position of the centre of the cyclone.

No.	Geographical area.	Direction of motion of prec. rear.	Direction of motion of cyclone.	Interval in hours.	Hourly rate of prec. rear. (miles)	Hourly rate of cyclone (miles)	Interval after pas. of cyclone. a (hours)	b. (hours)
23	Eastern Mass.	....	N. E.	....	....	50	5	....
27	Mass., R. I., Conn.	E.	N. E.	4	20	33	2	4
28	Whole area.	N. E.	N.	13	26	50	−2 *	6
29	Whole area.	N. E.	N.	11	28	47	— †	1
30	Conn , R I , Mass., Me.	N. E.	N. E.	16	12	21	1	6
31	Eastern Mass.	....	N. E.	....	....	38	2	....
34	Whole area.	E.	N. E.	14	12	33	−8 *	4

* The minus sign indicates that the precipitation ceased before the cyclone had passed. † Track in Atlantic and not charted.

A careful examination of the results collected in these tables seems to warrant the following conclusions, applicable to the cyclones of this class; the numbering is continued from the conclusions of the first division.

9. The precipitation is, with one exception large; if we include in this division cyclones Nos. 1, 11, 18 and 20 of the former division which were similar to those under discussion in their origin, but moved to the lakes before approaching New England, we shall find that the average maximum precipitation of the sixteen storms is 2.36 inches, while that of the seventeen remaining, which came from west or northwest is 1.74 inches.

10. The position of the maximum area of precipitation in relation to that of the path of the cyclone cannot be so well determined as in the former division on account of the narrowness of the territory on either side of the path. The average given in Table VI shows that the area is on the northwest of the average path, but this result may be fictitious, because the paths lie principally on the east of the territory covered by the observing stations, and the conditions further east are not known. In the former division, the investigation pointed to the conclusion that the maximum area of precipitation was not near the path of the cyclone, but well separated from it. In the cyclones of this class however, the testimony favors the conclusion that the maximum area lies on, or near the path.

11. The direction in which the front and rear of the precipitation advances deviates in certain instances (Tables VII and VIII) from that in which the cyclone is moving, but not to so marked a degree as in the former division. In general the two directions agree.

12. But the rate of progression is quite different. In no instance does the precipitation, front or rear, move as fast as the cyclone itself, (Tables VII and VIII). Averaging the eight cases, we find that the hourly rate with which the precipitation, front or rear, advances is 18 miles, that of the centre 33 miles. As the progression is northerly or northeasterly, this result means that as a storm centre approaches, it begins to rain or snow in the southern part of the district at a correspondingly earlier time than in the northern or northeastern parts.

WINSLOW UPTON.

(TO BE CONTINUED.)

THE CHINOOK WINDS.

I.—RELATIONS OF WINDS AND OBSTRUCTIONS.

There are many interesting phenomena connected with the wind which have not yet received the attention they deserve. In a fresh, quick rainfall with a strong wind one often sees by the raindrops, and feels in the force of the wind if he is in it, that the wind is passing in short waves of alternately greater and lesser intensity. Again, if one watches a surface of water in light winds he will observe that the wind appears to be deflected on the surface in limited spaces and spurts, and seems to ricochet from it again; and this can also be observed, though with more difficulty, when the wind is high.

When the wind meets with an obstruction, there is a series of complicated phenomena, the unravelment of which is rendered difficult by the fact that the moving liquid, the air, is invisible. If the obstacle is a limited one, there are eddies at its ends and a smaller one above. There is some quiet air in the lee of the obstacle and a smaller mass in front, but swirls of snow or leaves show that, though this air is not in progressive motion, it is more or less occupied by eddies. The form of the quiet masses is approximately shown by the snowbanks which form each side of a fence, but this is not an exact showing for the greater velocity of the wind just above the obstacle carries the flakes over a space each side without letting them fall; and the cohesion of snow sometimes causes the bank to trace out crests where the wind is not quiet, and to retain them even to the extent of forming a new obstacle and forcing the air-current a little out of its previous place. The whole art of snow fences, as practised by the railroads, depends on the effect of an obstacle in checking a current of wind enough to allow it to deposit its load of snow, and the snow fences that one sees on the transcontinental lines show that the study of the effects of obstacles on winds has been advanced, in the small, to a considerable degree.

But it is to the larger obstacles in the form of mountain ranges that we must turn our attention to explain the Chinook winds. The phenomena here are of the same general character as in the

case of small obstacles, except that certain mechanical principles, whose play in the case of the latter is utterly insignificant and inappreciable, become in mountain ranges important and well marked. The ascent of the current on the one side and its descent on the other occur in both cases, but in the case of the mountains, the width of whose base is greater than their height, it creeps up on one side without a general mass of quiet air, and its descent on the other is modified in the manner to be shown later. Besides, in the case of the mountain, the air may be forced up high enough to be chilled and lose much of its moisture, while on its descent it is more or less warmed up again. Meantime the irregularities of the mountain range, its peaks and saddles, its valleys and ravines, its outlying hills and rocks, all together cause a series of changes in velocity and direction and innumerable lees and eddies, the details of which vary with the place and are far too numerous, complicated, and local in character, to make it possible to discuss them.

The chief phenomena, noted above and about to be discussed in more detail, have been worked out in the study of a remarkable Swiss wind, called the *Foehn*, and have occupied the attention of the continental meteorologists since 1865 when, first Helmholtz, and a little later Tyndall, gave their explanation in the manner now all but universally accepted. In the credit of fully working out the details Dr. Hann, Dr. Muehry and Mr. Defour deserve a large share. The literature on the subject of the Foehn winds is now very extensive, and I shall attempt here to show that the Chinook winds are of the same character as the *Foehn*, but show the phenomena on a much larger scale.

Air when compressed becomes warm, when rarified it becomes cooler. It is the rapid compression of the air in front of them that causes the incondescence of the meteorites and an apparatus which compressed the air quickly and greatly has been used, in the place of matches, to light fires. On the other hand some of the freezing machines act through the cold produced by the rapid rarefaction of air. The air on elevations is rarer than that below. If a cubic inch of air from sea level were released on Pike's Peak it would spread until it occupied nearly twice as

much space, and if it were taken up in a balloon as high as Glaisher or Coxwell have gone, it would occupy three or four times as much space as at sea-level.

As the air is elevated it expands and, in the act of expansion, it cools. If the air is dry the cooling, at lower elevations, is one degree on Fahrenheit's scale for each 183 feet, so far as its temperature depends on its rarefaction alone. This is an ideal case, never actually realized in nature. Winds, clouds, the layering of the air by various causes, and many other things prevent the ideal case from ever becoming real. The chief source of interference, however, is to be found in the moisture in the air. The quantity of moisture which the air can hold decreases with the temperature, and, as the air rises and cools, it sooner or later reaches so low a temperature that the aqueous vapor begins to be deposited. Now water takes up heat as it evaporates, and must release it when it condenses. When the moisture begins to condense, it releases some heat, and the fall of temperature in the ascending air is checked. With a farther ascent and renewed cooling off more moisture is condensed, and the fall of temperature is again checked. These changes, here represented as a succession of steps, really occur continuously and, as a result, the rate of cooling of ascending air is less than one degree for each 183 feet. The rate now changes to one degree for about every five hundred feet so long as moisture is condensing.

The air, forced by the wind up a mountain slope, reaches the top cooled and more or less completely deprived of its moisture; it will not remain there, but its future progress depends on several conditions. Being rarefied, and consequently lighter than the lower air on the leaward side, one might expect that it would blow off at the same level, thus leaving the surface permanently. As a matter of fact, it does not generally do this. On the contrary it generally presents the same phenomenon that is seen in the case of a smaller obstruction. It leaps over a space beyond the obstruction and reaches the ground at a distance many times the height of the obstruction. The phenomenon is called a "wind fall" by Muehry from its analogy to a waterfall or cataract, but the analogy is a misleading one. The air in motion is imbedded

in its own mass, while the water falls in a much lighter fluid. A closer analogy would be found in some thread of a current at the bottom of a river. When it meets an obstruction it would not flow over as it would in air; it would stream off from the top, reaching the bottom again at some distance, being affected by friction on the mass in its way.

The so-called wind falls are seen in the smaller obstructions. When the snow-bank or sand-bank defines the space leaped over, the former probably with considerable accuracy. When the obstruction is as large as a mountain chain and there is no snow to define the limits of the relatively quiet leaward space, we can judge of the width of this "wind shadow" by seeing where the wind descends and again reaches the surface. Muehry gives an account of several in the *Austrian Meteorological Journal*, (Vol. III, 1868, pp. 10–33). On the west coast of South America such a wind-shadow extends along the coast of Chili and Peru from latitude 27° to 3° S. Here little rain falls, and stormy winds are unknown. The trade wind from the southeast here apparently leaps over the Andes and it is not felt again for some 200 miles to the westward. The Andes are some 12,000 feet high, and this makes the wind leap eighty times as far horizontally as it goes vertically. Similar, but less permanent, phenomena are found farther south in Chili, beyond the zone of the trades. A similar wind fall, for the same reasons, occurs on the west coast of Africa, but the coast chain of mountains is here much less high. Wind falls occur in many places—in Central America, Mexico, and Lower California, in Arabia, Persia, India, the Malay peninsula, and northern Sumatra, and even in the interior of continents as in Mesopotamia. The breadth of the wind-shadow is less elsewhere than on the coast of Peru; perhaps sixty times the height of the mountain chain is more usual.

But the wind fall is not the only way in which the cooled air comes down from mountains. Notwithstanding it is lighter than the lower air, it sometimes hugs the mountain surface in its descent, acting against gravity and displacing the heavier air underneath. An explanation of this apparent paradox is needed

and this explanation is found, according to Wettstein,* in the friction of the air with the surface of the ground. If a layer of shoemaker's wax be forced to flow down a rough inclined plane, its motions will be so slow that the effects of this surface friction can be seen in detail. The end of the flowing column is oblique, the upper layers projecting over the lower. These ends hang suspended and are prevented from flowing down over the ends of the lower layers only by the great viscosity of the liquid. If a less viscous liquid were taken, the ends would flow down, and with a very thin liquid, when the motion was rapid, they would topple over in a surge like breakers. The phenomenon is due to the friction of the lower layers, whose velocity is thus retarded, and Wettstein's conception is that this is what happens with the air. The lower layers being retarded by friction with the ground, the upper layers topple over them and, having thus a downward momentum, they are able to displace the air below, which, though heavier, is not much heavier than the air which forces it out of place. A similar action has been actually observed in flowing water where, on account of friction on the bottom, the water particles follow curved paths. If this is really an efficient cause for the descent of air from mountains, it is easy to see that its action would be especially great in ravines and narrow valleys, particularly near their heads, well up the mountains.

It is not, however, easy to acknowledge that surface friction, the action of which is not easily recognized in other wind phenomena, should give rise to the often violent winds of the *foehn.* Meteorologists have, therefore, searched for other explanations of this undoubted phenomenon, and Dr. Hann† has proposed a cause which commends itself at once as effective. The *foehn* is an incident in the wind system of a cyclone. The cyclones are so large that they are fairly indifferent to the mountain chains that lie in their way. They often pass over the the Rocky mountains without being apparently affected. When passing over mountains the general action of the cyclone forces the air

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* Die Stroemungen, etc., Zurich, 1880, p. 352.

† Handbuch der klimatologie, Stuttgart, 1883, p. 215.

up on the windward side, and the same general action tends to draw the air out on the leeward side. In exactly the same way as the cyclone tends to increase the pressure on one side of the mountains it tends to decrease it on the other. It exerts a mild suction on the leeward side and thus tends to draw the air away. By giving the leeward mass of air a motion from the mountains it enables the cooler air of the mountain top to come down and take its place. The greater weight of the leeward air no longers offers a resistance, as this air tends to stream away toward the center of low pressure. The very causes which force the air up on one side of the mountain, force it to hug the mountain slope on its way down on the other side.

The apparent paradox thus finds a complete explanation. It is worthy of note that this phenomenon can occur, it seems, only in a cyclonic area, and that the surface friction may materially aid its action. The great windfalls, on the other hand, occur only for steady, not cyclonic, winds. In the cases mentioned they occurred only in tradewinds or monsoons. We may conclude that *foehn* like winds are likely to occur only in the zones of variable weather and windfalls generally in the regions of steady winds.

It now remains to point out the characteristics of the wind which comes down from the top of a mountain obstruction. The windfalls are of no interest in the explanation of the Chinook winds, and we will consider only these winds which during their descent, hug the mountain side. With the sinking of the rarified air it becomes again compressed and as a result of the compression it warms up. Air is always warmed when it is compressed into a smaller compass. If the air is dry, and if there is no great loss of heat by evaporation or otherwise, the exact amount of change of temperature can be easily predicted when the atmospheric pressures are known for the top and for the place whose temperature is desired, and the temperature at the top is also known. The temperature is got from the equation which expresses the physical relations between the quantities

concerned.* The change of temperature may be considerable, in fact very appreciable. Thus for a range as high as Pike's Peak, if the temperature above is 32° F. and the pressure 18 inches, the increase of temperature for the descending air would be 6° or 7° for each thousand feet and, to a person descending, at 4,000 feet down the temperature would feel decidedly warm.

The exact difference of temperature observed would rarely be the theoretical. It would be likely to be lower, for reasons already mentioned, but it has sometimes been found higher. This is probably due to the fact that the temperature observed above is not that at the surface. Much of the air which reached the valleys below actually came from a much higher point, and consequently falls from a greater height, and hence had a lower pressure, than that employed in the formula. And probably the air from these higher levels, because of the intimate mixing by the currents, has not a much lower temperature than that at the surface where the observation is taken.

But there is another notable feature of the wind which comes down from a mountain under such circumstances. The air is not only warm, it is also dry. The capacity of the air to hold moisture increases with the temperature. The air on the mountain top has condensed its superfluous moisture and is saturated. As it descends and warms up, its capacity for moisture increases and it feels dry. The absolute humidity may remain the same but the relative humidity falls. If the leeward side of the mountain is arid, the air will feel parching, if the increase of temperature is considerable, and the effects on man and animals, and on vegetation, will be injurious. Timbers will be dried out and fires much more apt to occur. During a *fœhn*, a special fire patrol is put on in Swiss villages. If, on the other hand, there is abundant water or snow, the relative humidity will sink but not so rapidly. Evaporation will take place with great rapidity but not

*This equation is

$$t=\left\{\frac{p}{P}\right\}^{0.29}(460+T)-460,$$

where t is the temperature wanted. T the temperature at the top, p the pressure below. P that above.

rapidly enough to supply the air with all the moisture it can take up. Water exposed in pans will rapidly disappear; streams and ponds will dry up, and snow will fade away without causing any increase in standing or running water.

With the explanation of the descent of the air given by Dr. Hann we can account for the fact occasionally seen, that the warm, dry leeward wind may precede the moist windward one. The cyclonic action first causes a withdrawal of the air from the base of the mountains. This is replaced by air from the mountain top, which is warmed, and becomes dry in its descent. This leaves place for the ascent of the moist air on the other side of the mountains with the formation of rain or snow, which air in its time descends, warm and dry, on the now leeward side. The originating phenomenon is, in this case, not the ascent of a strong current, but the flow of a current on the opposite side toward a center of low pressure, and, in order of time, the warm wind precedes the wet storm of the opposite side. In such cases it is no longer a question of a current of air meeting an obstruction, but of a mountain heading off a current which starts, as most winds do, to leeward.

Another feature of such winds is that they would show seasonal peculiarities; the change in temperature would not only be more noticeable but actually greater in winter than in summer. The change in temperature for elevations is much less in winter than in summer; indeed in winter the tops of hills and mountains are sometimes warmer than in valleys. There are several causes for this, but whatever the causes may be, the facts are undoubted. This being the case the descending air in winter will bring down with it a much greater difference of temperature than it would in summer, and, moreover, the change will be much more noticeable. Moreover, in summer, the condensation on the windward side will be likely to set in only at a higher point, and the fall of temperature of the ascending air will be less retarded than in winter. The phenomenon will be less remarkable in summer and, when it occurred, it would be less noticed, for, at that season, it would be a change from a warm to a warmer temperature, while in winter it would be welcomed as a

marked amelioration of cold and as a means of causing the snow to disappear without floods. We may expect therefore that, where these winds occur, they will be noted as phenomena of the cold season.

The effect of the condensation of moisture on the windward side is to enhance the warmth and the dryness. The condensation retards the cooling and thus makes the air reach the top of the obstruction at a higher temperature. It, also, by removing the moisture, increases the dryness of the descending wind.

It is on account of the condensation that the descending current may be actually warmer than the ascending one. The windward air has its cooling checked by the condensation and thus reaches the top without the total fall of temperature to be expected on account of the elevation and rarefaction. On the other hand, the descending current, being on the relatively dry side, loses less heat by evaporation than was gained by condensation; it therefore reaches lower elevations with the theoretical increment, due to compression, almost unimpaired. Hence at any given level its temperature is likely to be higher than the temperature of the ascending air at the same level on the other side.

The distance to which the influences of such winds would be felt would vary with the topography. In Switzerland the *fœhn* is not felt far from the Alps but, in a more level region, the warmth and dryness might easily extend to great distances.

Under favorable circumstances, then, a mountainous obstruction would cause a warm dry wind on its leeward side. The Chinook winds are warm and dry, and I propose to show, in another paper, that they owe these features to the mountains among which they occur. M. W. HARRINGTON.

[TO BE CONTINUED.]

ON THE CONDITIONS THAT DETERMINE THE LENGTH OF THE SPECTRUM.

BY AMOS E. DOLBEAR.

[Communicated to the American Academy of Arts and Science.]

Professor Langley's conclusion as to the absence in the sun's rays of wave lengths as long as those to be found in the moon's rays has been a surprise to many, who for theoretical reasons have thought it to be well-nigh certain that all possible wave lengths were to be found in the sun's rays.

The common implication is that, when a body is being heated, the shorter wave lengths that appear are simply added to those already present, so that the spectrum's length is in a manner proportional to the temperature of the radiating body. If that was so it is difficult to see how there could be economy in electric glow lamps by simply using higher potential. It might give more light, but if at the same time the lower so-called heat-waves were just as numerous and with greater amplitude, that is, if the visible waves were not in any way the representatives of the energy of the lower end of the spectrum, then the amount of light would be proportional to the amount of energy expended, which is not the case.

Instead of that it increases as the 3d power. This great increase of the visible waves is then at the expense of the lower end of the spectrum, and any measure of the length of the spectrum from such a source would probably show marked decrease in the length of it between a low red and a white heat. This, too, is in accordance with molecular dynamics. If there be a gaseous volume of elastic molecules at any assigned temperature, the molecules collide and vibrate between impacts. Their rates of vibration must depend upon their molecular weight and elasticity, and similar molecules vibrate at equal rates. The characteristic wave lengths, or those by which a given gas may be identified, are produced by the vibrations between impacts, and the number of impacts per second will depend upon the gaseous density. Suppose a body capable of vibrating a times per second for its fundamental be struck b times per second;

then will its rate of vibrating be interfered with $\frac{a}{b}$ times. If b be less than a, then will there be a certain number of these vibrations made per second. If b be equal to a, then after the first impact the body will vibrate in its own period with increasing amplitude and without interference. If b be greater than a, then will interferences take place in all phases of the vibrations, and the body will not make any characteristic vibrations. That is, its fundamental rate will be destroyed. If the body can vibrate in any harmonic series, some of these harmonics might be present associated with such irregular forced vibrations above its fundamental number, and a spectrum of such a body would consist of such shorter waves. It would apparently be moved towards the blue end. If then the light-giving molecules of the sun have either so short a free path, or the velocity between impacts is so great, as to insure that the number of impacts per second is comparable with the vibrating rate of the molecules, one ought to expect that the fundamentals would largely be destroyed, and therefore could have no representations in the spectrum, while a colder body like the moon, with a vastly less molecular velocity, might have an appreciably longer spectrum.